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DUAL BAND RADOME WALL DESIGN

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INTRODUCTION

Radomes for currently-deployed air launched tactical missiles are typically designed to operate at a single frequency or narrow range of frequencies, and occasionally over a wider band of contiguous frequencies spanning an octave or slightly more. Requirements to operate against an extended threat suite, and/or to negate probable countermeasures tactics, indicate a need for future systems to encompass a multi-mode capability. Such systems will combine operations in two or more discrete segments of the electromagnetic spectrum in an integrated seeker unit. Possible mechanizations include combinations of RF/IR, IR/UV, passive RF/active RF, and microwave/millimeter wave bands. Multimode systems such as these will naturally require a matching capability from the radome.

A high-speed, streamlined radome presents a difficult enough design problem even for single-frequency applications; when it is required to provide clean transmission in two discrete bands, the difficulty is greatly increased. The conflict between the requirements of low aerodynamic drag, adequate structural integrity, and good electrical performance is brought even more sharply into focus, and the design tradeoffs and resulting compromise configuration must be approached with extreme care.

The first essential step in the process is necessarily the selection of a material or combination of materials, and appropriate thicknesses for each of them, which will result in adequate transmission of electromagnetic energy at the desired frequencies over the anticipated range of incidence angles. This is not the most difficult design task; the design of the radome shape and tailoring the wall thickness profile is expected to be more critical, as is the integration of a dual-mode seeker in a co-aperture or co-axial configuration. Nevertheless, the design cannot proceed without the prior selection of a suitable radome wall configuration.

Because of the increased complexity of these walls, a far greater range of feasible solutions than usual will be possible, and optimum designs will be more difficult to determine. Even if the radome design task is initiated early, in parallel with the seeker design, a significant tradeoff study will be necessary to identify the best materials combinations and wall configuration for the intended application.

The groundwork for this effort can be accomplished in a timely manner, through a preliminary evaluation of suitable materials matched to projected electrical requirements. Computer analysis can permit the identification of promising wall configurations, exhibiting desirable electrical properties in physically realizable thickness combinations. This paper describes two dual-band walls designed in this manner.

SPECIFIC DESIGNS

As the number of layers in the radome wall is increased, the magnitude of the design task grows considerably, and some means of computer-assisted design becomes necessary. Even for walls of only two or three layers, the examination of possible combinations of material types and thicknesses is greatly facilitated by automated codes to characterize the transmission of the candidate wall configuration as a function of thickness, frequency, incidence angle, and polarization. The plotted data in the following figures was generated by one such code, Flight Systems, Inc., WALLTX flat plate analysis simulation, which has been used to develop conceptual radome wall designs for a number of applications. Included among these are walls designed to support discrete dual-band operation. Examples of two such designs are described in the following paragraphs.

Alumina Dual Band Radome Wall Design

Figure 1 is a cross section through a ceramic three-layer wall designed for a generic X-band/Ku-band application. The materials represented in this design are alumina (the skins), and a proprietary ceramic foam material, Cerez, manufactured by Omohundro Company. This wall configuration was one of nine developed under U.S.

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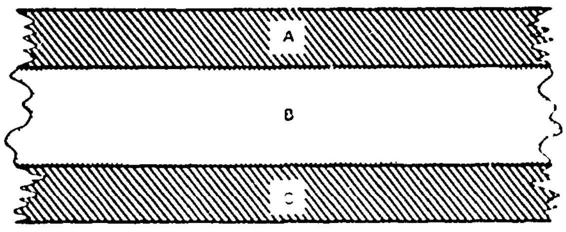
Navy contract number N00123-79-C-1042 in 1981. The selected materials were at that time under evaluation at the Naval Weapons Center, China Lake.

Several physical configurations of the symmetric three-layer wall were examined using the WALLTX analysis and design simulation, which allows the thickness of one or more layers to be varied at a given frequency to determine the optimum thickness. Fixing first one layer, then the other(s), and observing the transmission at the two frequencies of interest, the program may be used in an iterative fashion to arrive at a desired configuration such as that shown in Figure 1.

This wall is a rather unusual combination of thick skins on a thin core, and the resulting 57.5/100/57.5 configuration has a well-defined resonance at 10 GHz, plus two useful passbands at about 30 and 36 GHz (Figure 2). The phase grouping is unusually tight at the 10 GHz resonance, and on the basis of detailed analysis in the 5-15 GHz regime, would appear to offer the potential of performance at least equal to, if not in excess of, a 10 GHz-tuned half-wave wall. The transmission summary in Figure 2 shows the transmission coefficient for both parallel and perpendicular polarization at a single incidence angle in each plot. The broken line curve is the zero-incidence transmission coefficient, for reference. The curves show that the wall maintains transmission better than 75 to 80 percent at both 10 GHz and 36 GHz out to 80 degrees incidence angle. Although the high passband frequency is a little higher than the desired 35 GHz value, the resonance could be adjusted to this value through small changes in wall thickness.



SECTION THROUGH RADOME WALL

LAYER NO	MATERIAL TYPE	DIELECTRIC CONST	LOSS TANGENT	THICKNESS (MILS)
A	Alumina	9.50	0.0002	57.5
B	Cerez	2.41	0.0024	100.0
C	Alumina	9.50	0.0002	57.5

Figure 1. Alumina/Cerez Dual Band Radome Wall Configuration

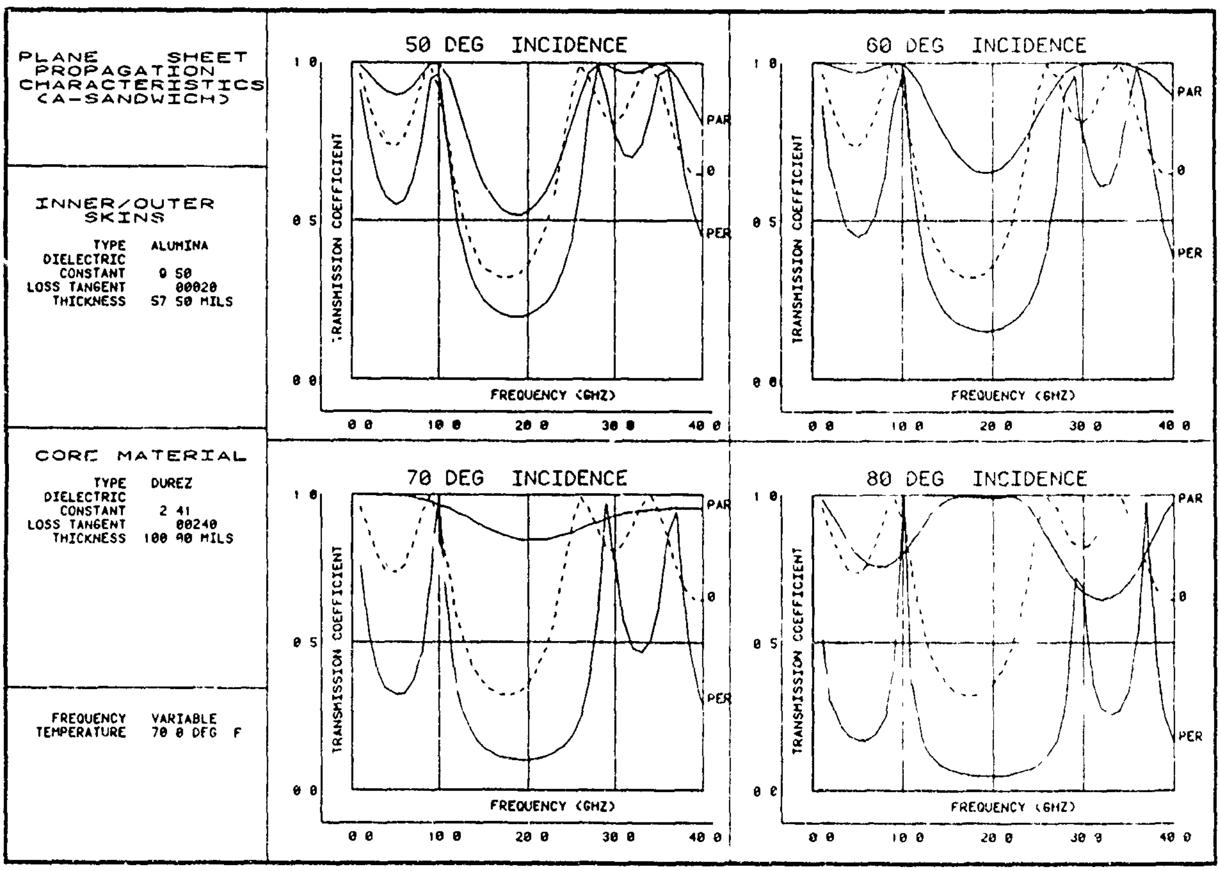
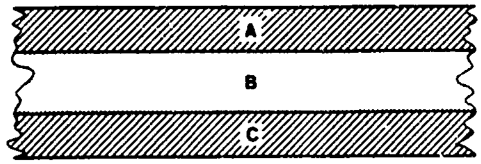


Figure 2. Transmission Summary, 0-40 GHZ, Alumina/Cerez Wall

Silicon Nitride Dual Band Radome Wall Design

The "transportability" of this design was shown in a subsequent analysis task in which the radome wall was redesigned for a specific application using silicon nitride (Figure 3), a material with good thermal shock resistance and a low susceptibility to rain damage. Various forms of this material have been considered for high speed missile radome applications by both the Air Force and the Navy. By controlling the density of the material during manufacture, the dielectric constant of silicon nitride may be tailored to a specific requirement. The design illustrated in Figure 3 uses a moderate-to-high density reaction bonded formulation (with good rain erosion resistance) for the skins (Ref. 1), and an extremely low density core made by baking out inclusions introduced during the initial manufacture to produce a silicon nitride foam (Ref. 2) of low dielectric constant.

The resulting 69/90/69 wall configuration has thicker skins but a slightly thinner core than the alumina version, and the overall thickness of 0.228 inches is comparable with a conventional single-mode X-band wall. The electrical performance of this wall is very similar to that of the Alumina/Cerez wall, as Figure 4 shows. The wall exhibits peak transmission windows at 10.5, 30, and 36 GHz as before, and though the resonance peaks are not quite so strong at the high incidence angles, they are adequate for low-loss transmission over bandwidths of



SECTION THROUGH RADOME WALL

LAYER NO	MATERIAL TYPE	DENSITY (GM/CM^3)	DIELECTRIC CONST	LOSS TANGENT	THICKNESS (INS)
A	Reaction-Bonded Silicon Nitride	3 025	7 60	0003	069
B	Silicon Nitride Foam	0.89	1 93	0003	090
C	Reaction-Bonded Silicon Nitride	3 025	7 60	0003	069

Figure 3. Silicon Nitride Dual Band Radome Wall Configuration

500 MHz, as shown in the two following figures.

Figure 5 details the electrical performance of the wall over the frequency range 9.5 to 10.5 GHz. The upper left plot shows the phase difference for incidence angles up to 85 degrees; the other three plots are similar to those in Figure 2 and depict parallel and perpendicular transmission coefficients at 60, 70, and 80 degrees incidence respectively. These latter plots show that the transmission of

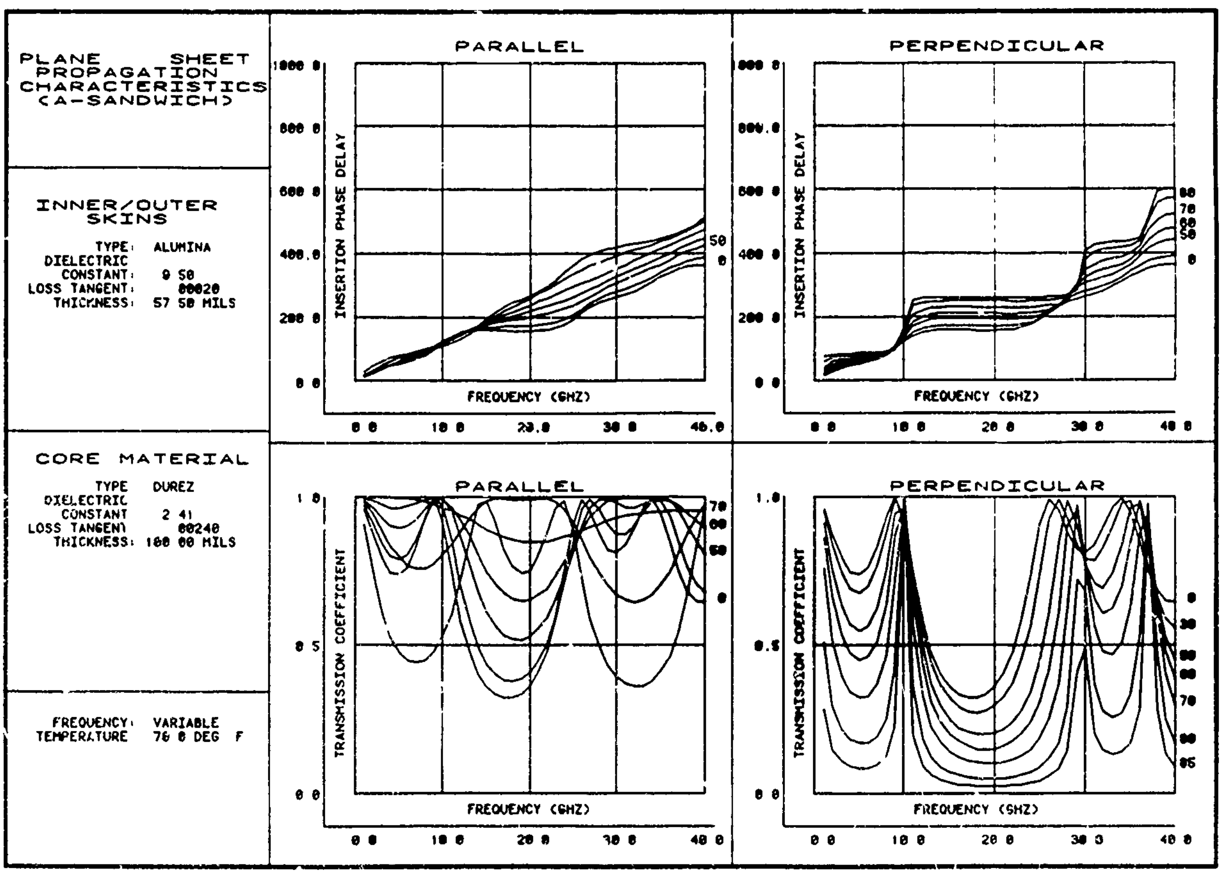


Figure 4. Electrical Performance, Silicon Nitride Dual-Band

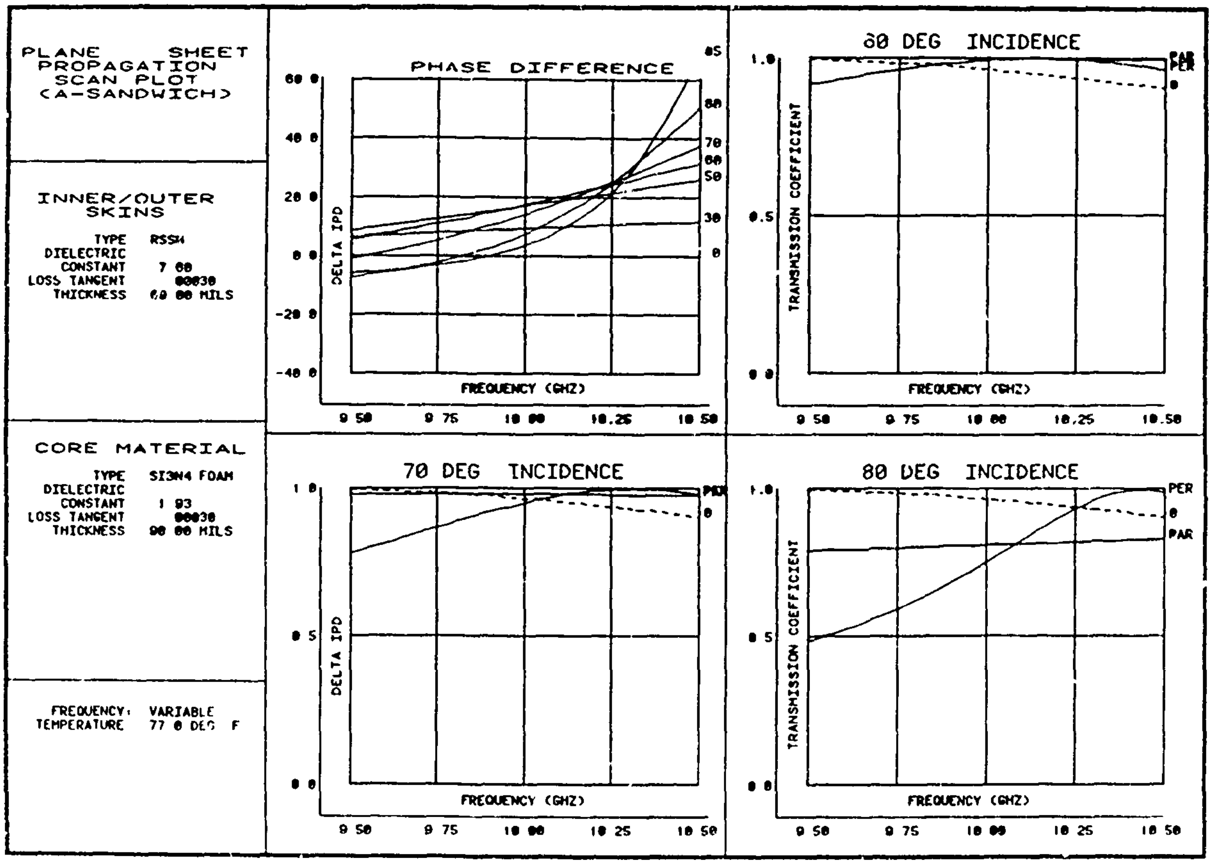


Figure 5. Performance Detail at 10 GHz, Silicon Nitride Dual Band Wall

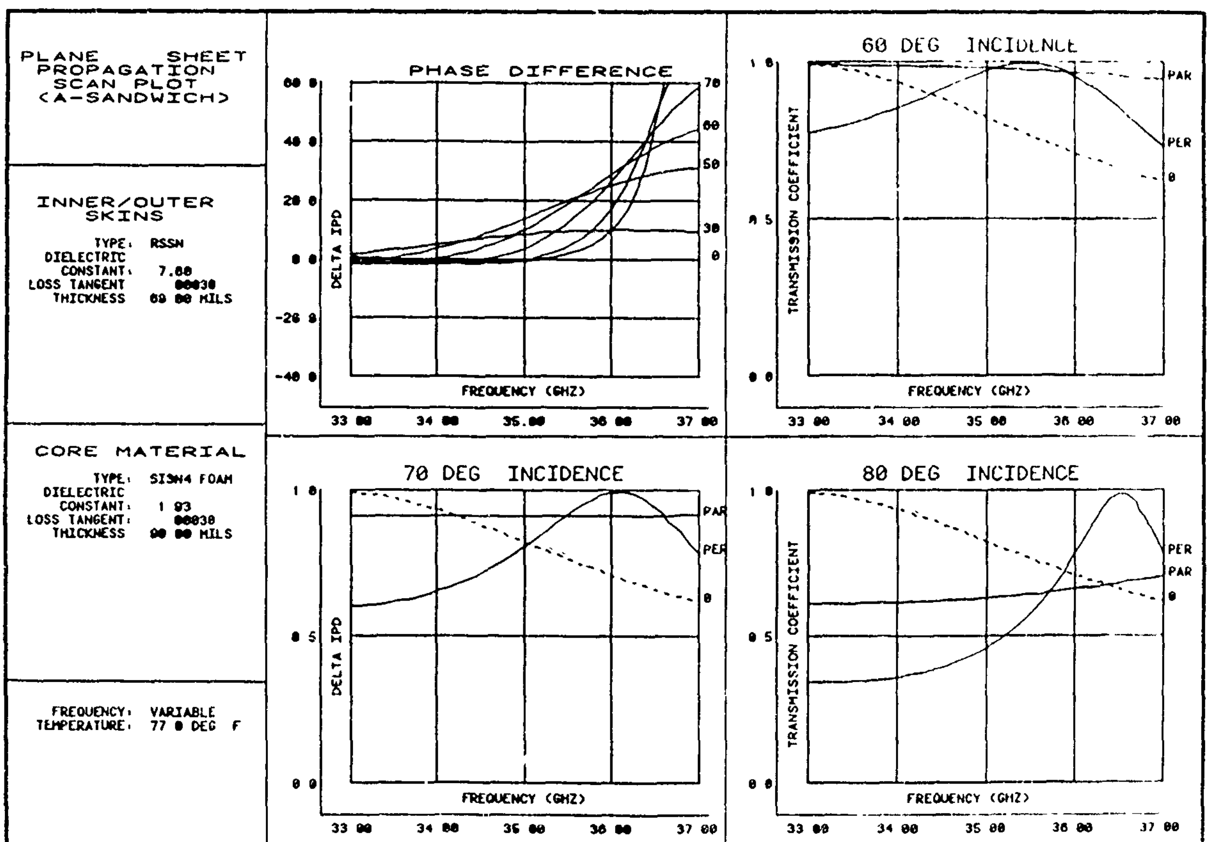


Figure 6. Performance Detail at 35 GHz, Silicon Nitride Dual Band Wall

the wall is excellent up to 70+ degrees incidence across the 9.75 to 10.25 GHz band, and is maintained well even at 80 degrees. The phase difference values over this frequency range lie within a band of values from -10 to +30 degrees, performance consistent with the attainment of low boresight errors and error slopes.

At 35 GHz the performance, though not quite as good as at 10 GHz, is still quite impressive (Figure 6). Transmission is maintained well to 70 degrees incidence, but is beginning to degrade badly at 80. The phase difference also holds up well out to 35.6 GHz for incidence angles of 70 degrees or lower. A full-aperture seeker at this frequency would be expected to suffer about 1 dB of loss (one way), and to introduce moderate guidance errors in a proportionally guided missile. If the high frequency aperture could be reduced, however, the range of incidence angles experienced would be limited and an overall performance might be attained suitable for high quality end-game guidance. With further refinement the design would be expected to yield improvement in both bands. It exhibits a useful characteristic at frequencies other than the design passbands; it transmits very little energy at these other frequencies (Figure 4), and would therefore make a contribution to a system designed for low-observable operation. The design in general certainly merits further investigation.

CONCLUSIONS

The two radome wall designs presented in this paper were derived inexpensively using computer-aided analysis techniques. Useful performance potential is predicted in configurations employing a variety of materials, and novel wall configurations were developed which may find application in multi-band seeker applications as well as systems benefiting from stealthy operation.

The author believes that the computer aided design technique for conceptualizing and screening wall configurations in this way can make a significant and useful contribution to the radome design process by identifying workable configurations in advance of system-specific requirements, thereby reducing the lead time required for design solutions and assisting the weapons system procurement process.

REFERENCES

1. J. Barta and M. Manela, "Preparation and Properties of Silicon Nitride for Radome Applications", Proc. 16th Symposium on Electromagnetic Windows, G.I.T., June 1982.

2. F.H. Simpson and J. Verzemnieks, "Controlled Density Silicon Nitride Material", Proc. 16th Symposium on Electromagnetic Windows, G.I.T., June 1982.